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Investigation of Gas Absorption Models from 22GHz to 58GHz in the Atacama Desert

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Motivation

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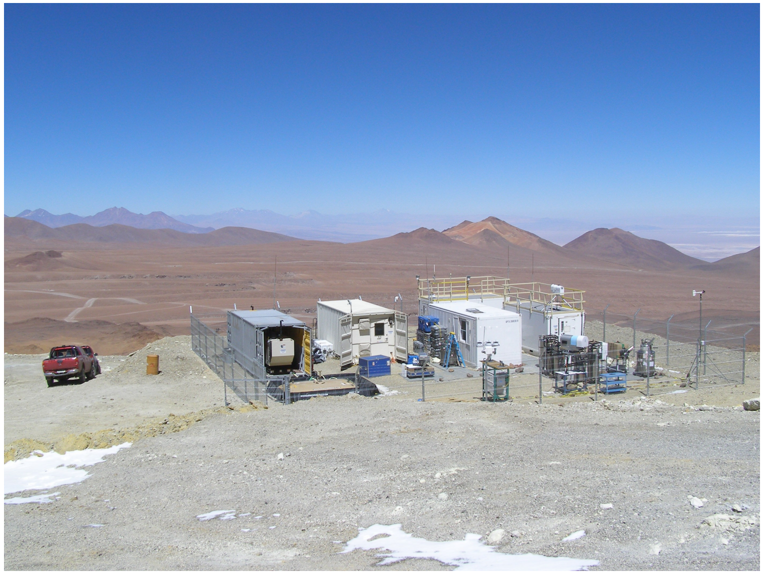
- A realistic simulation of atmospheric absorption and emission is needed to improve the spectroscopy of remote sensing applications
- In the microwave gas absorption models can deviate from each other by several Kelvin - depending on frequency/atmospheric conditions
- Absorption line parameters are mostly derived from laboratory measurements – field observations shall be used for validation
- The field campaign RHUBC-II offers a unique data set of high spectral-resolution radiative observations of the middle-to-upper troposphere at low pressure/humidity conditions over a wide spectral range

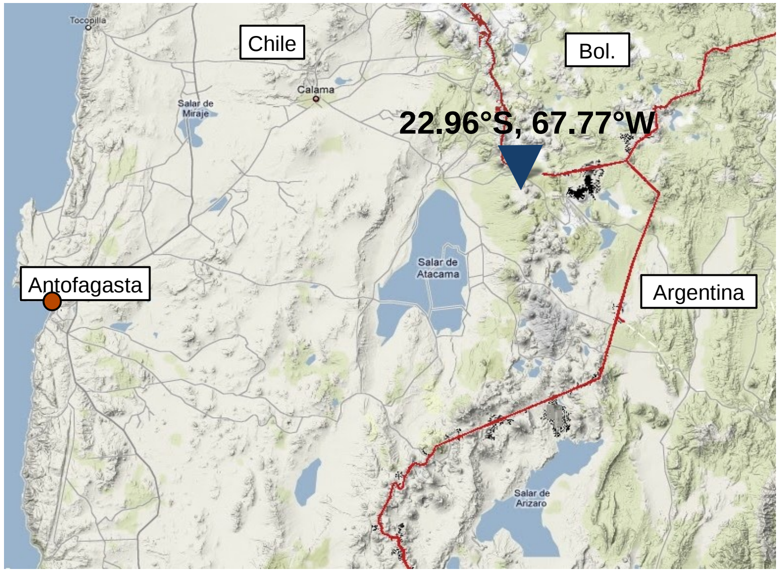
→ **Evaluation and improvement of gas absorption models**

- Comparison of zenith brightness temperatures (TB) observed at the surface by a microwave radiometer and TB simulated by gas absorption models
- Estimate the accuracy and error sources of observed/simulated TB

Field Campaign - RHUBC-II

- August-October 2009: 2nd phase of Radiative Heating of Underexplored Bands Campaign within the **A**tmospheric **R**adiation **M**easurement Program
- Site at 5322m/ 530hPa at Cerro Toco, Atacama, Northern Chile: extremely low water vapor conditions
- Focus: characterize/improve gas absorption models in spectral regions that are normally opaque at sea level using high spectral-resolution observations.
- Aim: Better implementation of radiative forcing in global climate models





RHUBC-II site at Cerro Toco, Chile

Field Campaign - RHUBC-II

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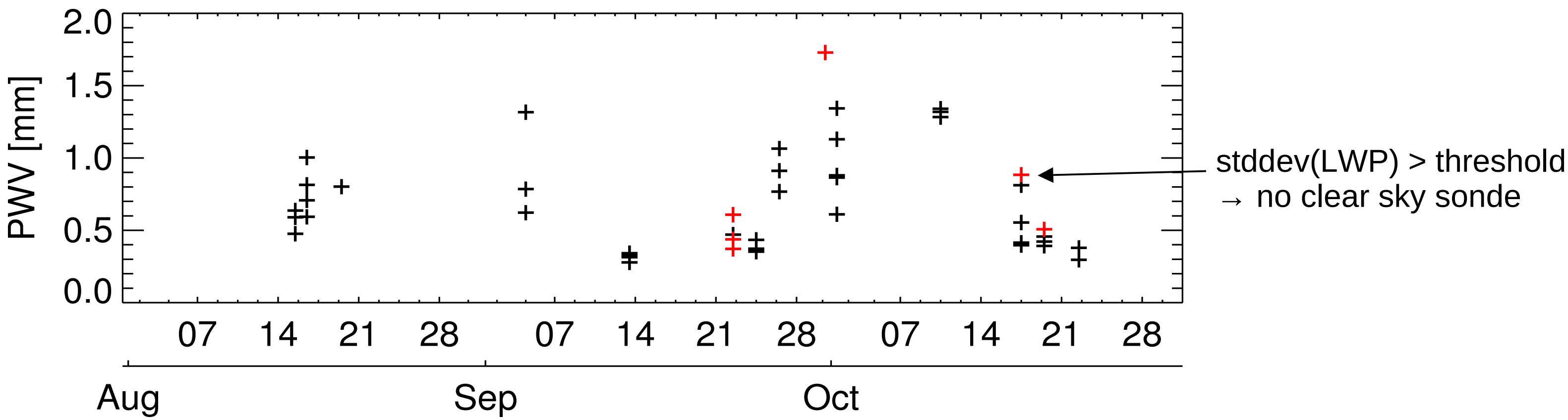
- Constant surface conditions: daily means from synoptic station: 266±3K, 532±2hPa, 23±15%
- Dry atmosphere: annual precipitable water vapor (PWV): 0.1-5.0mm
- 41 clear sky radiosondes (Vaisala RS92-K) simultaneous to brightness temperature (TB) observations between 22 and 58GHz



MW	**HATPRO**	Humidity and Temperature Profiler
	GVRP	G-band Vapor Radiometer Profiler
	SAO FTS	Sub-mm Fourier Transform Spectrometer
IR	**REFIR**	Radiation Explorer in the Far InfraRed
	FIRST	Far InfraRed Spec. of the Troposphere
	AERI	Atmospherically Emitted Radiance Interferometer
VIS	**ASTI**	Absolute Solar Trans. Interferometer
	MFRSR	MultiFilter Shadowband Radiometer

Radiometric Instruments measuring for RHUBC-II

Gas Absorption Models

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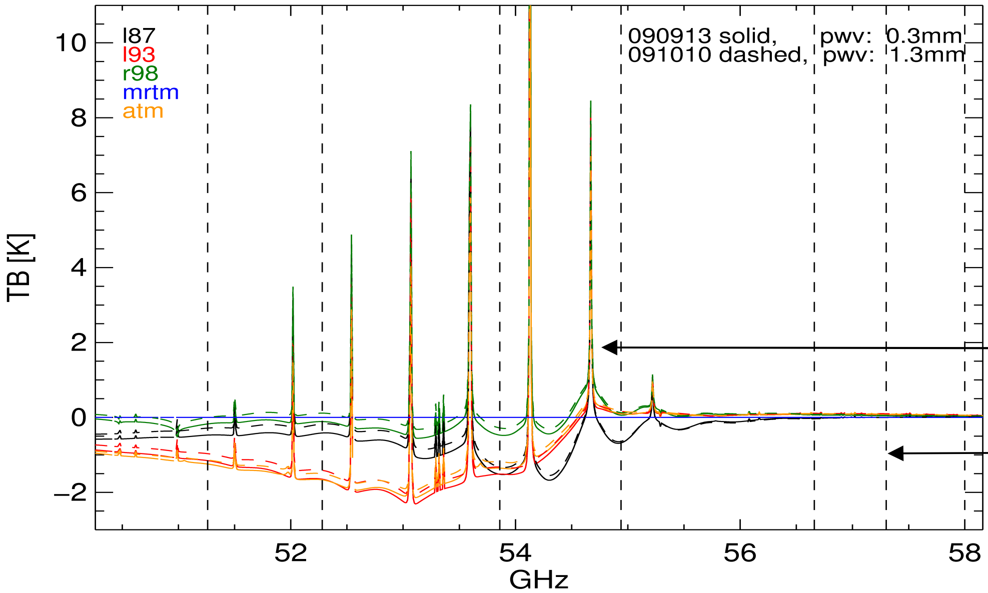

Liebe'87
Liebe'93
Rosenkranz'98
ATM
MonoRTM4.2

- Line-by-line zenith TB calculations at surface for downwelling radiation
- Atmospheric input: radiosonde profiles of T, p, q
- Line parameters derived from laboratory measurements
- Absorption of H2, O2 and N, no trace gases, no scattering
- Coupling of pressure-broadened aborption lines is involved

→ High resolution spectrum at the oxygen absorption complex at 60GHz gives a model spead of up to **2K** for the background and differences of more than **10K** at the Zeeman peaks

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Microwave Radiometer - performance

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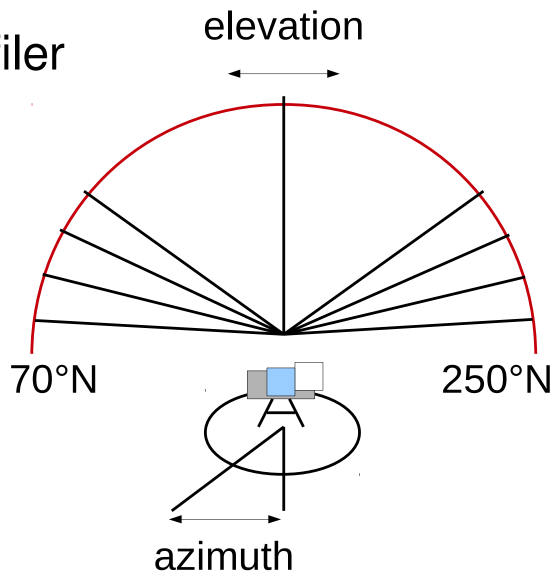
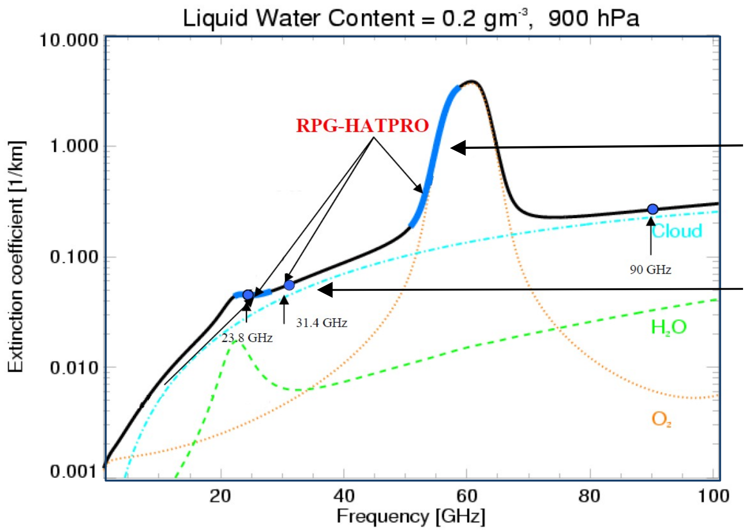
- **HATPRO-G2**: Humidity and Temperature PROfiler Generation 2
- **14 channel** total-power microwave radiometer channels are characterized defined by sharp bandpass filters
- high accuracy **brightness temperature (TB)** (0.5K, 1s integration time)
- elevation scans in a fixed azimuthal plane (1.0, 1.4, 2.0, 3.0, 6.0, 12.0 air masses)



HATPRO at RHUBC-II



7 V-band channels ($O2$ absorption)

7 K-band channels ($H2O$ absorption)

source: HATPRO manual , RPG

Microwave Radiometer – absolute calibration

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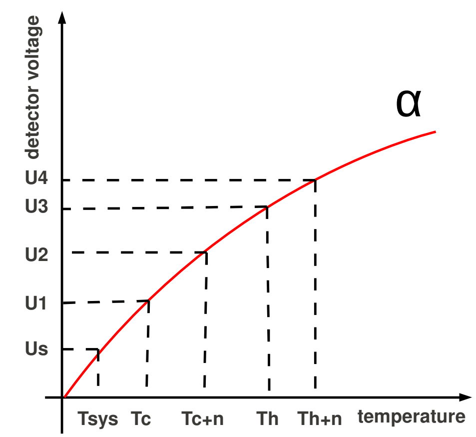
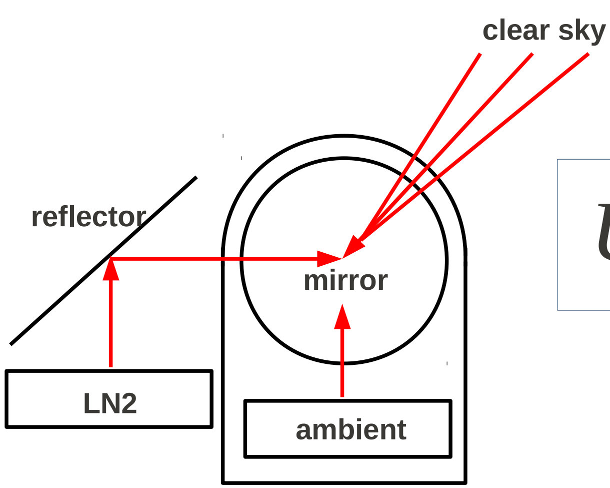
- **4-point calibration:**
  LN2 target (*Tc*), ambient target (*Th*) and noise injection (*Tn*). System noise (*Tsys*), gain (*g*) and non-linearity factor (*α*) are determined.

- **Tipping Curve:**
  for transparent radiometer channels the cold target (*Tc*) can be replaced by the clear sky. It is calculated from elevation scans (opacity/air mass pairs) and the mean radiative temperature of the atmopshere (*Tmr*). Precondition: horizontal homogeneity

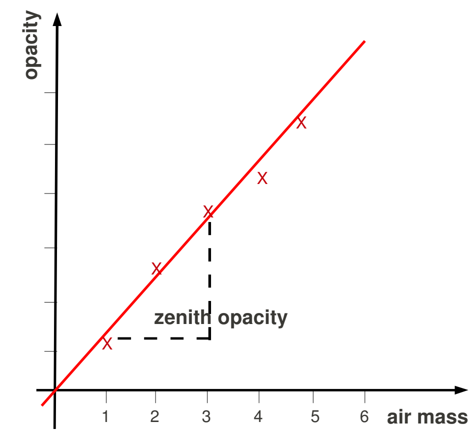
4-point scheme





$$U = g \cdot P(TB)^{\alpha}$$

Tipping curve



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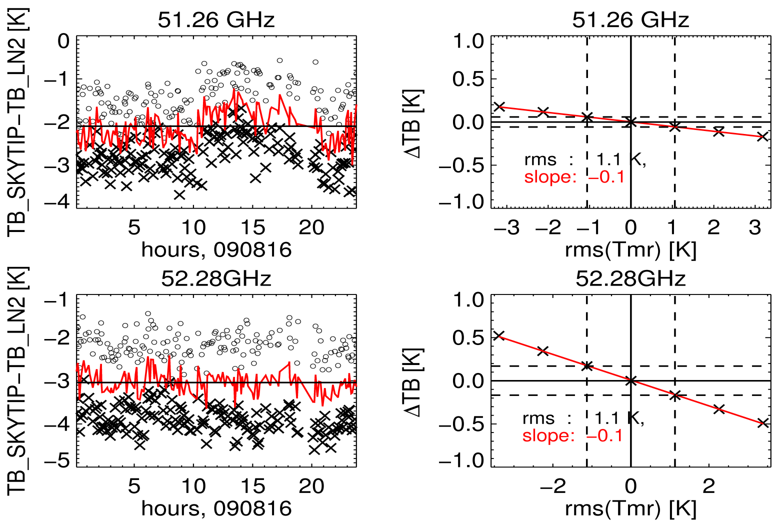
Microwave Radiometer – tipping curve calibration

At 530hPa O2 channels at 51GHz and 52GHz are transparent enough to be calibrated by the tipping curve method:



- 156 elevation scans on Aug 16, 2009 down to 4 air masses are used to derive mean calibration factors (0.946/0.946, good repeatability = homo geneous conditions), opacity/air mass correlate by >0.9998
- An instrument tilt of 0.2° is balanced by averaging TB of symm. elevations
- Compared to the LN2 calibration TB_MWR is reduced by **2.1K/3.0K**
- Tmr is derived from surface temperature. Its uncertainty has an effect on the calibration by **<0.5K**

Results – Model vs. Measurement

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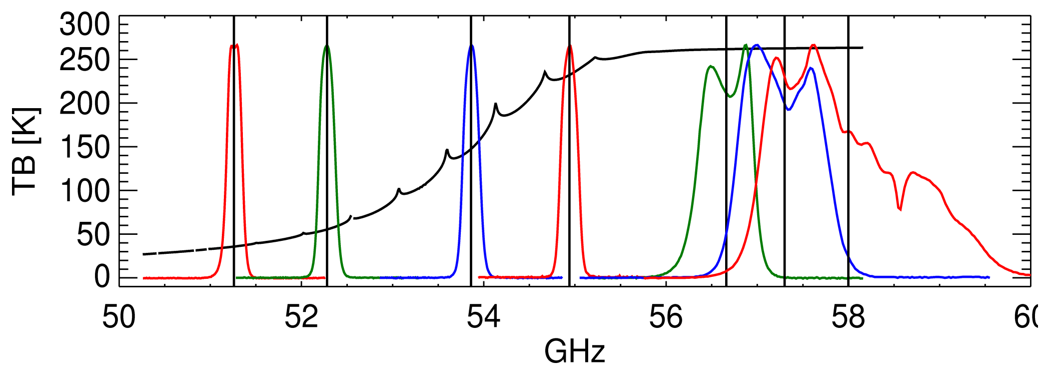
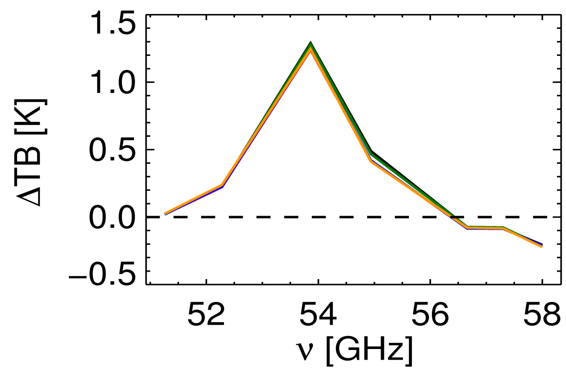
- Modeled TB are convolved with exact band-pass filter traces
→ difference of up to **1K** compared to TB calculations at mid-frequencies for channels on the spectral slope





- The sensitivity of modeled TB to biased temperature and humidity profiles is <**1K**. Only close to H20 line center (22GHz) the uncertainty of the humidity profile significantly affects TB (**2K**)

- Radiosonde profile have to be extended above the tropopause. Several climatological profiles have been used - all with the same radiative effect (up to **15K**)

Results – Model vs. Measurement

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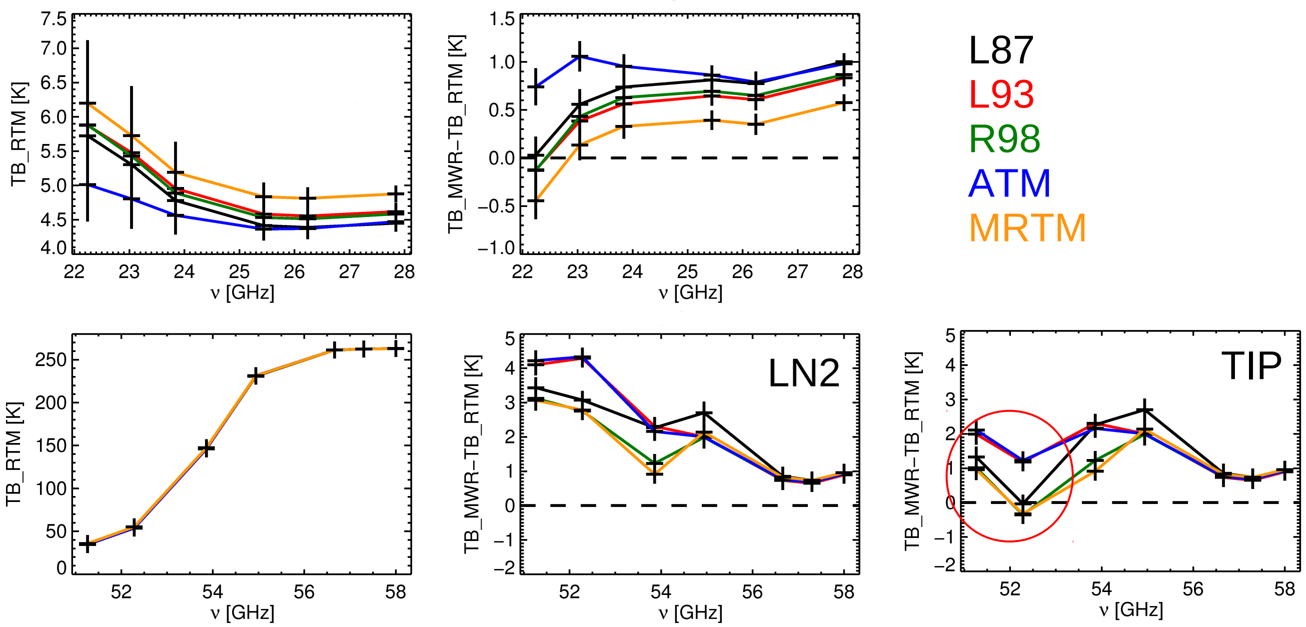
Comparison of zenith TB from HATPRO and different absorption models



- At HATPRO channels the model spread is up to **1.5K**
- K-band: the radiometer is capable to detect the very weak water vapor line at a very low signal-to-noise-ratio (0.03)
- V-band: TB discrepancy of **0.5-4K** is reduced by the tipping curve calibration at 51GHz and 52GHz

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Summary & Outlook

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Summary

V-Band:

- Existing absorption models deviate by up to 2K at HATPRO channels
- Discrepancy between simulated and measured TB is 0.5-4K
- Exact bandpass filters have to be considered in a TB comparison
- Simulated TB is not influenced by biased radiosonde profiles
- Measured TB depends on the absolute calibration method (LN2 - tipping curve = 2-3K at transparent O2 channnels)

K-Band:

- Good radiometer performance at very low signal-to-noise-ratios (22GHz)
- Potential influence of biased humidity profiles from radiosondes

Outlook

- Analyses on the accuracy of LN2 calibrations
- Measurements-to-Model comparison at 183GHz (water vapor)
- Adapt model line parameters to better fit radiometer measurements

Thank you!